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METEOROLOGY.—*The murmur of the forest and the roar of the mountain.*[1] W. J. HUMPHREYS, U. S. Weather Bureau.

INTRODUCTION

Certainly for many centuries, perhaps from even the cave and stone age when men first began to associate one phenomenon with another, the murmur of the forest and the roar of the mountain have each been recognized as a meteorological symphony with the drive of the wind and the stress of the storm for its theme. As some one has pleasantly put it,

"The whispering grove tells of a storm to come."

And Lucan, the Roman poet, nineteen hundred years ago, solemnly warned us:

"Nor less I fear from that hoarse, hollow roar
In leafy groves and on the sounding shore."
—Rowe's translation.

Ages before this in turn Elijah told Ahab to hurry and eat and get down from Mount Carmel "for there is a sound of abundance of rain." And this sound, it would seem, could have been none other than the murmur of the forest, mingled, perhaps, with the roar of the mountain. "And it came to pass in the mean while, that the heaven was black with clouds and wind, and there was a great rain."

Such, then, has been the recognized weather significance through the ages of these mysterious aeolian effects. In many regions it is now, as it has long been, and as it indefinitely must continue, a common thing to refer to the "roaring" of a mountain as an indication of a general storm within six to twelve hours; and the "sign" is an excep-

[1] Presidential address.

tionally good one. Among the Alleghenies, to be specific, where the prevailing trend of the ridges is from northeast to southwest, this roaring is most persistent and pronounced with strong southeast winds. But these are the winds of the forward, or rainy, side of a cyclone whose center happens, as is often the case, to be 300 miles, or less, west to northwest of the place in question; hence the strong probability that the roaring of these mountains will soon be followed by bad weather. In these storms, averaging, roughly, two a month during summer and twice as many during winter, a number of distinct meteorological phenomena, including the roaring just mentioned, are often observed, the more conspicuous and more important of which it will be interesting, perhaps, to describe and profitable to explain.

The particular region here referred to, and in which the phenomena under discussion frequently occur, is the Gap Mills valley of Monroe County, West Virginia, between Peters Mountain, one of the finest of the Alleghenies, to the southeast, and Gap Mountain to the north-

Fig. 1. Cross section of Peters Mountain and adjacent region

west. A cross section of this region, not, however, at the highest part of Peters Mountain, approximately to scale—2½ miles from crest to crest—is given in fig. 1. Some four miles beyond the crest of the larger mountain, to the southeast, is that of another mountain nearly as high, namely, 3800 feet, roughly, above sea-level and 1200 feet above the adjacent valleys. Beyond this in turn are still a few other ranges, mostly smaller, however, and more irregular. A typical view of the Gap Mills valley in which the roaring of the mountain and associated phenomena are so pronounced, and of Peters Mountain that does the roaring and causes most of the other phenomena to be discussed, is shown in fig 2. The Gap Mountain is off the picture to the right. The ridge in the middle background, known as Jesse's Ridge, and averaging about 200 feet in height, often is the cause of interesting secondary phenomena.

DESCRIPTIONS AND EXPLANATIONS

Although the murmur of the forest, the roar of the mountain, the winds that cause these sounds, and the usually accompanying clouds

and precipitation all are closely interrelated, some of them even in the sense of cause and effect, nevertheless, and for convenience, they are here discussed severally, and more or less independently, the whole constituting what might, perhaps, be regarded as a chapter on mountain meteorology.

(L. W. Humphreys, photo.)

Fig. 2. Peters Mountain and Gap Mills Valley

Opposing winds near top of mountain.—There occasionally are strong winds simultaneously up both sides of a high mountain ridge, such as Peters Mountain, near its top, when there are only light winds, or none at all, on the lower slopes and in the adjacent valleys. The explanation of this condition, which may or may not be associated with the coming of wide-spread cloudiness and extensive precipitation, consists of two parts: (1) How there may be a strong wind only near the top of a mountain, with but little or no appreciable movement of the air lower down and in the valleys. (2) How a strong wind can blow up one side of a mountain near its top at the same time that another strong wind is blowing up the other side, also near the top.

That a gale may exist across a mountain crest while the air is relatively calm below, is obvious from the facts (*a*) that adjacent layers of the air frequently have very different velocities, especially when the upper part of the under layer is colder than the under part of the upper layer, a condition that often occurs, and that permits the two distinct layers to flow, the one over the other, with but little intermingling, much as air flows over water; and (*b*) that in mountainous regions cold air, whatever its origin, tends, through its increased density, to fill the valleys and to become entrapped in them. Occasionally, therefore, the valley atmosphere, up nearly to the crests of the flanking mountains, is comparatively quiet while the air next above is moving rapidly directly across the trend of the ridges, and, of course, up so much of the windward sides of the mountains as projects into this over current.

But at the same time this wind of such obvious origin is blowing up one side of a mountain near its crest, a wind in the opposite direction, and also shallow, is rushing toward the crest up the other side. The explanation of this counter current, the second portion of the problem under discussion, requires a little of that strait-jacket logic of the physicist.

Let, then, the wind be in a steady state, constant at any place in direction, velocity, temperature, and density, and consider a tube of flow, that is, an imaginary tube of whatever size along which the air is flowing and across whose walls no air passes either in or out, just above the top of the mountain; let m_1 be the mass of air that passes the crest during a given interval of time along this tube; let v_1 be the volume of this mass as it passes, p_1 its pressure, and u_1 its velocity. Similarly, let m_2, v_2, p_2, u_2, be the corresponding values during the same interval of time for any cross section of the tube beyond the crest. Then, since the wind is in a steady state, $m_1 = m_2$. Furthermore, the simultaneous flows of energy along the tube by these two cross sections are also equal, because, as specified, no changes are occurring at any place. Finally, if the change of temperature of the surrounding air with change of altitude is strictly in keeping with the corresponding change in pressure—and in winds that are of the breeze order or stronger it is nearly so owing to their considerable stirring up, or turbulence—then the gravity contribution to the potential energy of a mass of air as it passes from one level to another is negligible, or, in other words, no appreciable work is required to lift a mass of air to a greater height or to pull it down to a lower level. There-

fore, to a close approximation, the sum of the volume energy and the velocity energy is constant. In symbols,

$$p_1v_1 + \tfrac{1}{2}mu_1^2 = p_2v_2 + \tfrac{1}{2}mu_2^2$$

or

$$v_1(p_1 + \tfrac{1}{2}\rho_1u_1^2) = v_2(p_2 + \tfrac{1}{2}\rho_2u_2^2)$$

in which ρ is the density. Hence, per unit volume,

$$p + \tfrac{1}{2}\rho u^2 = a\ constant.$$

Now, observation shows that ρu^2 is greatest near the crest of the mountain, as it is along the edge of any obstruction to a moving fluid. Clearly, then, this is also the place of least pressure within the tube of flow. Therefore, air must rush into the general current at this place (the assumed steady state cannot exist) and thus induce a corresponding wind up the lee side of the mountain near the crest.

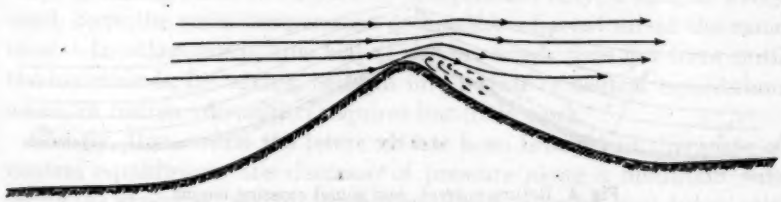

Fig. 3. Opposing winds near top of mountain

The above explanation embodies a form of the well known Bernoulli Theorem, hence it belongs to that finality class that precludes quibbling. Nevertheless, it is not quite so final as it seems, for viscosity was omitted, although, as everyone knows, contiguous portions of the atmosphere are so knit together by the thermal motions of their molecules that every blast of air more or less drags along the immediately adjacent air. This drag in turn leads to boundary turbulence and momentum interchange. Hence the upper portions of an under layer of air are caught up by any swifter wind above, and increasingly so with increase of velocity. In this manner also, in the case under consideration, the pressure in the surface air just beyond the top of the mountain on the lee side is decreased, and a wind up that slope is established and maintained.

When the upper wind crosses the valley at mountain height, as often happens, and as here assumed, the return current rapidly becomes

weaker, with distance down the slope, owing to surface friction and to the rapidly increasing cross section of the inflow, as indicated in fig. 3.

Exact mathematical and quantitative solutions of this and kindred problems, involving viscosity and turbulence, would, no doubt, be highly instructive, but such solutions have not been obtained. True, important progress has been made, but this progress, which is found chiefly in the turbulence papers of Rayleigh, Reynolds, Taylor, and Richardson, is not adapted to a brief and inclusive summation.

Return current.—When there is an appreciable wind from the mountain, there often is a lighter surface wind in the opposite direction up portions of the mountain itself, as indicated in fig. 4, and up the lee side of any paralleling ridge in the valley. This, too, has no necessary relation to the gathering of clouds and the onset of precipitation, since it applies equally to winds crossing the mountain in

Fig. 4. Return current, and sound crossing mount

either direction. It differs from the opposing wind near the top of the mountain, just explained, in that it extends much farther down from the crest.

In this case the valleys contain but little if any stagnant air; the wind flows across the mountains in undulations more or less parallel to their sides, and the change of temperature with change of elevation is everywhere, owing to turbulence, in keeping with the corresponding change of pressure. That is, the change of temperature is due entirely to change of pressure, and not at all to loss of heat to, or gain of heat from, anything extraneous to the rising or falling mass of air.

In general the explanation of the return current is precisely the same as that given above of the opposing winds at the crest, except that as its cross section remains small (the parent wind being only a little above the surface) its velocity is correspondingly retained over a considerable distance down the mountain side.

During clear days the return current is strengthened by thermal convection; during clear nights, on the other hand, it is weakened if

not overcome or even reversed, by the tendency of the air along the slopes, owing to increased density due to loss of heat to the surface which, in turn, had cooled by radiation, to drain, or flow, away to lower levels.

Tempest belt.—When the wind across the mountain is strong, which it seldom is except in connection with a general cyclonic storm, it often beats down heavily on a narrow belt near, or beyond, the foot of the mountain—the stronger the wind the farther to leeward the tempest belt—while the winds both in the valley beyond and up the higher slopes are comparatively light, the latter indeed often being up the mountain and hence opposite in direction to that of the crossing and stronger wind. This tempest belt does not appear until the lower air, through the turbulence caused by the upper winds, has been brought to the same potential temperature throughout; that is, to such condition that each rising mass of air, if cooled by expansion only, or falling mass, if warmed by compression only, would, at every level, have the same temperature as has the adjacent air at the same level. In other words, this belt of driving winds does not form until the lower air is, by mixing, brought into a state of neutral equilibrium when, of course, convection requires but little work.

Clearly, then, when the lower air has been brought to this state of neutral equilibrium, the decrease of pressure along a mountain side owing, as explained above, to crossing winds, may be, and frequently is, sufficient to cause these winds to flow down closely parallel to the lee slope. The inertia of this descending current carries it on, and hence it often beats strongly on a belt near the foot of the mountain, where the slope has become gentle, or even somewhat out in the valley. Furthermore, just as the wind strikes with a downward component onto this belt, so too it rebounds from it with an upward component. Hence, beyond the tempest belt the winds are comparatively weak.

But the above may not explain the worst of these tempest winds. Since, as already stated, there are several mountains southeast of, and parallel to, Peters Mountain, and since the rains and snows of greatest duration come from that general direction, it follows that these mountains, and the valleys between them, get more precipitation than does the valley and adjacent section northwest of this highest ridge. Hence, occasionally, the former region may be snow covered and relatively cold while the latter has but little snow and is appreciably warmer. Under these conditions southeast winds on topping

Peters Mountain must, because of their comparatively great density incident to the low temperature, rush cataract-fashion down the lee side and onto the nearer portion of the valley. At such times the winds of the tempest belt are abnormally violent, and much like the famous Helm Wind along the west side of the Pennine range of mountains in northern England.

It may, perhaps, be worth while to call attention here to the all but obvious fact that when the lower air has been brought to neutral equilibrium, which it soon is after the surface winds become strong, an aviator can more easily cross a high mountain with the wind than against it—more easily when the currents boost him up than when they beat him down.

Smoking of chimneys.—When the wind is from the mountain it frequently happens that chimneys near its base, and even many in the valley, "smoke" in a most disagreeable, puffy, manner, a phenomenon locally interpreted to imply the approach of bad weather, a prediction that usually comes true. The cause of the smoking of chimneys at the time of winds from the mountain is, of course, perfectly obvious. As just explained, these winds have marked downward components, and some of the gusts are strong enough to drive well into an open topped chimney against the heated air, and send smoke and ashes whirling through the room. Hence in mountainous regions many chimneys are hooded as a protection against both the smoke nuisance and its inevitable fire hazard.

Sounds beyond the mountain.—At the very beginning of a general storm and before any other evidence of it is apparent, sounds made in a windward valley, or beyond, often are distinctly heard in the next valley to the leeward where at other times they are quite inaudible. This effect clearly is owing to the fact that the vibrating air, transmitting the sound with the velocity of about 1100 feet per second, is itself a part of the general wind. Since the velocity of sound has been closely determined for certain temperatures, and is known to vary as the square root of the absolute temperature, it follows that for any given variation of temperature with altitude and given corresponding direction and speed of the wind the path of any sound ray—any normal to the sound-wave front—can be traced with all desired accuracy. Under certain simple conditions, such as uniform changes of temperature and wind velocity with altitude, the path of a sound ray can be given in terms of a concise equation. However, it is not worth while here to indulge in any such mathematical diver-

sions, because actual winds are not so regular as these exact solutions would require, and because the general effect can best be shown graphically. Let, then, the wind blow more or less directly across a mountain, up one side and down the other parallel to the surface, and increase with distance from that surface, all of which occurs in nature. Obviously a sound wave-front travelling with such a wind tends more and more towards the vertical as it climbs the windward side of the mountain, crosses the ridge substantially upright, when the distance to the source and the wind velocity are in proper adjustment, and then focusses onto the leeward valley, all as diagrammatically illustrated in fig. 4, in which S is the source of the sound, and F its leeward focus, necessarily diffuse, as determined by the wind currents and indicated by the progressive positions of the wave front.

Roaring of the mountain.—At about the time the above transmontane noises are heard, or shortly thereafter, the mountain over which they come begins to produce a low sighing or moaning sound which in a few hours, particularly during winter, when the winds are strong and have free access to the eddy and vortex-producing twigs, often grows to a cataract roar.

This roaring of the mountain is a very striking phenomenon, especially to any one not accustomed to it. To the imaginative who know its cause, it ranges from the beautiful to the sublime; while to the superstitious it may run the whole gamut of horrors from the uncanny to the demoniacal, as illustrated by the following tradition:

It seems that the ridge shown in fig. 2, and which is about a mile and a half long, was owned first, some 150 years ago, by one Jesse Bland. But he soon lost it, it is said, by deeding half his place to a "witch doctor" to cure him of the witches, whose direful threats carried by the howling wind were ever more clamorous with the swell of the mountain's roar, and who night after night transformed him to a horse and furiously rode him 200 miles for a bag of salt—so he explained his night sweats—and shortly afterwards the remaining half to a lawyer to sue the witch doctor for not curing him. Today in this enchanting valley there lives neither witch, witch doctor, nor lawyer. Its people believe neither in folly nor in fuss. But the mountain still roars and at times one can sympathize with Jesse, or with the Esthonians of today who, attributing, we are told, the bitter northerly winds of spring to the spells of Finnish wizards and witches, are afraid to go out on Ascension Eve, or either of the other two Days of the Cross:—

"Wind of the cross! rushing and mighty!
Heavy the blow of thy wings sweeping past!
Wild wailing wind of misfortune and sorrow,
Wizards of Finland ride by on the blast."
—Popular Esthonian song.

The explanation of these curious sounds evidently goes back, not to wizards and witches as might formerly have been supposed, but to the action on the wind by a single twig or branch, for the differences between the whispering of the tree, the murmuring of the forest, and the roaring of the mountain, are essentially differences in degree and not of kind.

Now, it has long been known from the work of Strouhal[2] that wind normal to a cylinder, such as a stretched wire, produces aeolian tones even when the cylinder itself takes no part in the vibration; that the pitch of the note thus produced, independent alike of the material, length, and tension of the wire, varies directly as the speed, u, of the wind and inversely as the diameter, d, of the obstructing rod; and that the number, n, of such vibrations per second is given, approximately, by the equation

$$n = 0.185\ u/d$$

the units being the centimeter and second.

An excellent example of such sounds is the familiar singing or humming of telegraph and telephone wires.

Whenever the tone produced as above described coincides with one of the proper tones (fundamental or a harmonic) of the wire, the wire itself, if suitably supported, then vigorously vibrates, normal to the direction of the wind, and thereby increases the loudness and produces other interesting results. These, however, will not be considered further since the twigs and branches of trees, whose aeolian effects alone are here under discussion, have no free periods of importance in this connection.

The sounds in question, that is, the tree and forest sounds, therefore, are not due to the elasticity of the twigs and branches, but, as in the case of the singing telegraph wires, to the instability of the vortex sheets their obstruction introduces into the air as it rushes by them. This obvious and, indeed, unavoidable deduction from Strouhal's experiments, just referred to, has been abundantly confirmed by cinema photographs of water eddies, due to flow past a cylinder. Vortex whirls develop in the flowing water at regular

[2] Ann. d. Phys. **5**: 216. 1878; see also Lord Rayleigh, Phil. Mag. **29**: 433. 1915.

intervals, alternately on the one side and then on the other, of the interfering cylinder, while the eddy mass vibrates from side to side in the same period.

The complete mathematical analysis of these and similar vortices, giving the deduction of Strouhal's rule, and many others, would be both interesting and valuable, but it appears that this important problem has not yet been fully solved. Clearly, though, if all twigs and branches had streamline shapes—shapes over and along which a current of air will flow without vortex agitation—and were properly oriented to the wind there would never be a whisper from a tree nor

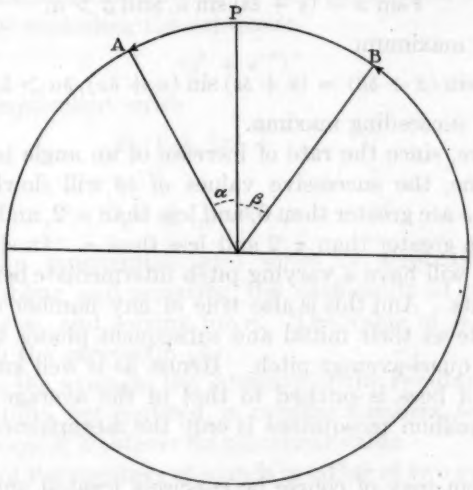

Fig. 5. Phase circle

murmur from a forest. But they are not so shaped; trees do have voices, and voices that are even characteristic of the species. The muffled plaint of the oak at the wintry blast, for instance, has but little in common with the sibilant sigh of the pine. And the reason is obvious. The twigs and branches of the one, because relatively large and of many sizes, produce a multitude of low tones, while the innumerable fine needles of the other give a smaller range of high-pitched notes.

It remains now to determine how a multitude of sounds, such as twig-produced aeolian notes, blend together—how the pitch and loudness of the resultant are related to the like properties of the elementary constituents.

Let two sounds have the same amplitude, but slightly different frequencies, a and b, $a > b$. Let them start together with maximum displacement, or at the top, P, of the phase circle, fig. 5. Let the phase position of the quicker, after a few intervals, and at the instant when the resultant amplitude is at a maximum, be at A (having described the angle $2n\pi + \alpha$, n being a whole number) and that of the slower at B (having described the angle $2n\pi - \beta$); let s be the velocity along the circumference of the phase circle of the slower, and $s + \delta s$ the correspnding velocity of the quicker. Then, since the combined amplitude is at a maximum,

$$s \sin \beta = (s + \delta s) \sin \alpha, \text{ and } \beta > \alpha.$$

For the next maximum

$$s \sin (\beta + \delta\beta) = (s + \delta s) \sin (\alpha + \delta\alpha), \delta\alpha > \delta\beta,$$

and so on for succeeding maxima.

Furthermore, since the rate of increase of an angle is greater than that of its sine, the successive values of $\delta\beta$ will slowly increase so long as β and α are greater than 0, and less than $\pi/2$, and then increase while they are greater than $\pi/2$ and less than π. In short, the combination tone will have a varying pitch intermediate between those of its constituents. And this is also true of any number of constituent sounds—whatever their initial and subsequent phases their resultant always has a quasi-average pitch. Hence, as is well known, the hum of a swarm of bees is pitched to that of the average bee, and the concert of a million mosquitoes is only the megaphoned whine of the type.

This problem may of course be concisely treated analytically, but the above simple method is sufficient for the present purpose.

The final law of sound essential to the explanation of the roar of the mountain, namely, the intensity of a blend in terms of that of its constituents, has been found by Lord Rayleigh[3] in substantially the following manner:

Let the number of individual sounds be n, all of unit amplitude and the same pitch, but arbitrary phase—conditions that approach the aeolian blend of a forest, or even a single tree. Clearly, if all the individual sounds had the same phase, and unit amplitude, at any given point, their combined intensity at that point would be n^2. If, however, half had one phase, and half the exactly opposite phase, the intensity would be zero. Consider then the average intensity

[3] Encyclopaedia Britannica, 9th ed., "Wave Theory." Scientific Papers 3: 52.

when all the vibrations are confined to two exactly opposite phases, + and −. Now, the chance that all the n vibrations will have the same phase, + say, is $(\frac{1}{2})^n$ and the expectation of intensity corresponding to this condition $(\frac{1}{2})^n n^2$. Similarly, when one of the vibrations has the negative phase and the $n-1$ others the positive phase, the expectation is $(\frac{1}{2})^n n(n-2)^2$; and the whole or actual expectation

$$(\tfrac{1}{2})^n \left\{ 1.n^2 + n(n-2)^2 + \frac{n(n-1)}{1.2}(n-4)^2 + \ldots . \right\} \qquad \text{(A)}$$

The sum of the $n + 1$ terms of this series is n, as may be indicated by a few numerical substitutions; or proved, as Lord Rayleigh (*l. c.*) has shown, by expanding the expression

$$(e^x + e^{-x})^n$$

into the two equivalent series

$$2^n (1 + \tfrac{1}{2}x^2 + \ldots \ldots)^n \qquad \text{(Maclaurin)}$$

and

$$e^{nx} + ne^{(n-2)x} + \ldots . \qquad \text{(Binomial)}$$

developing the exponentials into series of algebraic terms, and, finally, assembling and equating the coefficients of x^2 in the two equivalent series, and solving for n. The value of n thus found is identical with the expression (A).

That is, on the average, the intensity of the resultant of n sounds of unit amplitude, but confined, in random numbers, to two opposite phases, is always n, whatever its numerical value.

If, instead of the numbers of sounds in either of two opposite phases being random, the phases are random, the result, as Rayleigh has shown, is the same.

It should be noted that n is only the mean intensity of a possible range from 0 to n^2, and not the continuous intensity. But when the changes are rapid the fluctuations from the mean are correspondingly inconspicuous.

From the above two laws, namely, (1) that the pitch of a composite note is the approximate average of those of its constituents, and (2) that the mean intensity is the sum of the individual intensities, it appears (*a*) that the pitch of the aeolian murmur of a forest is essentially that of its average twig, or needle, if the forest be of pine, and (*b*) that though the note of the twig may be inaudible, even at close range, the forest often may be heard miles away.

The explanation of the roar of the mountain, most pronounced during winter when the trees are bare and the winds strongest, is now obvious. It is only the feeble notes of the myriads of forest twigs at and near the mountain top merged into a mighty volume of sound of a more or less average pitch, all focussed, as shown by fig. 4, on the valley beyond, but so crudely and variably focussed as to cause great fluctuations in the intensity.

Clouding of mountain crest.—At the same time, approximately, that the mountain begins to roar, its crest usually becomes cloud capped, even when all other portions of the sky are absolutely clear. As already explained, this roaring commonly is in response to the strong and persistent winds on the forward side of a cyclonic storm, the side where, because the wind is from the southeast, roughly, the clouds thicken and rain begins. As also previously explained, the wind is necessarily from the southeast over Peters Mountain when its roar is heard in the adjacent northwest valley—the particular circumstance here under discussion. Of course this mountain, and others similarly oriented, roars to its opposite, or southeast, valley in response to northwest winds; but these winds generally are relatively weak or of comparatively short duration and the roaring they produce correspondingly inconspicuous. They, therefore, will not be further considered in what follows.

The southeast winds, then, over this mountain, coming, at least in their greater distances, from relatively warm and humid regions, progressively approach saturation. Furthermore, it is the under layers, in general, of the air that contain the largest amount of moisture, partly because of their higher temperature and consequent greater moisture capacity, as we elliptically (if not even cryptically) express it, and partly because the source of this humidity—bodies of water, and growing vegetation, chiefly—is at the surface of the earth.

After a time, then, the lower layers of the atmosphere become so humid that their cooling by expansion as they rise over the mountain carries their temperature below the dew point, and thereby produces a cloud along the mountain crest. At first this cloud, continuously formed by condensation on its windward side, is continuously evaporated on its leeward side. That is, it is a stationary cloud though its every droplet is in rapid motion and of short duration. It is a local condition in the flowing air just as a waterfall is a local condition in the passing stream.

Drifting of scud.—The leeward side of the crest cloud, just explained, is dragged out in irregular fragments by the gusts and swirls of the

passing wind and driven, as flying scud, down the mountain to quick oblivion—rapid disappearance through evaporation, owing to the increase of temperature that results from the gain of pressure always incident to loss of level.

Isolated cloud billow.—As the scud fleeces grow in size and number, a detached cloud bank of the roll-cumulus type forms over the leeward valley parallel to the mountain crest. At first this cloud is narrow and often broken, but it soon grows wider, deeper, and darker. It is more or less agitated, but as a whole remains fixed in position.

The inertia of the air, as it sweeps up and over the mountain, carries it to an elevation more or less above its level of equilibrium, from which elevation it drops back farther on, and again, like the swinging pendulum, passes beyond its point of rest. In this way a few rapidly damped billows are set up parallel to the mountain crest just crossed. That is, the air rises first above the mountain, then falls to a lower level, rises

Fig. 6. Stationery clouds on mountain and over valley

again (affording the soaring bird easy toboggan sailing), and so on in rapidly decreasing amplitude. Hence, as the humidity of the air increases, first a slight cloud forms a little above and to the leeward of the mountain ridge along the crest of the topping billow, while the crest of the next billow beyond, being at a lower level and therefore warmer, is entirely cloudless; then, with further increase of humidity, this initial cloud thickens until it rests on the mountain top and gives off continuously avalanches of scud—scud that evaporates in its first descent, condenses on rising to the next billow crest, and again evaporates as it passes on and down the farther side of this aerial wave, all as schematically illustrated in fig. 6.

It is this convectionally-recondensed scud at the crest of the first air wave beyond the mountain ridge that constitutes the isolated roll of cumulus cloud along the leeward valley, a cloud that is continuously formed and as continuously evaporated, a permanent cloud of fleeting particles, and stationary because the crest of the billow is fixed in position.

By, and commonly before, the time this stationary cloud has formed over the valley, the air has become so thoroughly mixed that most of the wind phenomena described above are fully developed. In particular the descending currents reach the earth along the tempest belt and there rebound, giving the mysterious leeward calm beyond.

Complete clouding.—Commonly the crest cloud along the mountain grows heavier, the scud thicker and more enduring, and the bank of stationary cloud over the leeward valley broader and deeper until all merge together and the whole sky is blotted out by a continuous cloud canopy; a sequence of phenomena owing entirely to the increasing humidity of the air, and the consequent lowering of the dewpoint, as the wind continues to blow from warmer and more humid regions.

Rain or snow.—Shortly after the clouds have merged into a continuous sheet, precipitation usually begins, and commonly lasts anywhere from several hours to an entire day, or even two days. It is the final result, in part, of the increased humidity of the winds, and also in part of the convection and consequent cooling of the air incident to the cyclonic storm then prevailing.

After the rain, or snow, there follows, of course, the process of clearing up, but this process has no distinct mountain peculiarities and hence need not be discussed here.

There are of course still other phenomena that might be considered in this connection, but the above are, perhaps, the more interesting and the more important of the many generally associated with the roaring of the mountain, and enough to assure us that among forested mountains, especially

"In winter, when the dismal rain
Comes down in slanting lines,
And Wind, that grand old harper, smites
His thunder-harp of pines,"—

—Alexander Smith.

when the muffling leaves are gone and the twigs are free to mingle their myriad aeolian tones, the coming storm is heralded by the murmuring of the forest and the roaring of the mountain. In proverb form:

When the forest murmurs and the mountain roars,
Then close your windows and shut your doors.

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PHILOSOPHICAL SOCIETY OF WASHINGTON

872D MEETING

The 872d meeting was held in the Cosmos Club auditorium, Saturday, November 18, 1922. It was called to order at 8:25 p.m. by President CRITTENDEN, with 40 persons in attendance.

Mr. C. E. VAN ORSTRAND addressed the Society on *Deep-Earth temperatures in the United States*. The address was illustrated by lantern slides, and was discussed by Messrs. CRITTENDEN, HEYL, PAWLING, GISCH, WHITE, HUMPHREYS, PRESS, and HAWKSWORTH.

Author's Abstract: The application of electrical methods to the determination of temperatures at great depths was discussed, but the instrument which seems best adapted for general use in making a geothermal survey is the maximum thermometer. Apparatus for use in connection with maximum thermometers was described. Tests in a great number of wells show that an accuracy of 0.1 or 0.2°C. can be obtained when working under favorable conditions. The chief source of error is the lack of temperature equilibrium in the wells.

A brief discussion of the data of observation from mines, and both flowing and non-flowing wells, was given. This feature of the investigation has not yet been carried to a point where definite conclusions can be stated.

A paper by K. S. GIBSON and E. P. T. TYNDALL, on *The Visibility of Radiant Energy* and illustrated by lantern slides was discussed by Messrs. PAWLING, PRESS, and CRITTENDEN.

Author's Abstract: By the visibility of Radiant Energy is meant the ratio of luminosity to radiant power at the different wave-lengths (or frequencies) in the spectrum. In cooperation with the Nela Research Laboratories, a new determination of this function had been made at the Bureau of Standards. The so-called "step-by-step" method was used, which is an equality-of-brightness simultaneous-comparison method, in which there is little or no color difference in the two parts of the photometric field. Fifty-two observers were tested, some of them common to previous investigations.

The final results are not greatly different from those obtained in other investigations, and comprise further evidence on the comparison of equality-of-brightness and flicker photometry.

INFORMAL COMMUNICATIONS

W. J. HUMPHREYS referred to the various factors that appear to enter into the determinations of latitude. Among others, it had recently been found in England that there appears to be a variation of latitude with the velocity of wind. The question was further discussed by Messrs. WHITE, LAMBERT, and PAWLING.

Mr. PAWLING reported that recently he had made a setting with a telescope at the U. S. Naval Observatory on a star that apparently was not catalogued. He was uncertain whether it was a variable start, or one that had been accidently omitted from the Star catalog.

SCIENTIFIC NOTES AND NEWS

Mr. A. E. RUARK gave the second of the series of lectures on the Quantum Theory at the Bureau of Standards on January 15, 1923. The quantum theory of spectroscopy and the Balmer series of hydrogen were discussed, the fundamentals of the theory being taken up in historical order. Mr. Ruark dealt with the two suppositions made by Bohr to explain the spectrum lines of hydrogen and the ionized helium atoms:

(1) When the atom is not radiating, its single electron and its nucleus move in circles around their common center of gravity in conformity with ordinary dynamics, but the circles on which they can move are restricted to a finite number by the *quantum condition* that the angular momentum of the entire atom must be an integral multiple of $h/2\pi$ where h is Planck's constant; however, the nucleus is so heavy compared to the electron that it moves on a circle very small in comparison to the electronic orbit.

(2) When the electron passes from one of these circles to another, where the system has less energy, the energy E which is given up is transformed into a train of light waves of frequency ν, where ν is determined by the equation $E = h\nu$. Sommerfeld has extended the theory to the case of elliptic orbits, and has discussed the effect of change of mass of the electron due to its velocity thus obtaining an explanation of the fine-structure of the hydrogen and helium lines. Wilson and Sommerfeld have formulated the general quantum conditions which determine the discrete orbits possible in any system of particles with conditionally periodic motion; these include Bohr's postulate concerning the angular momentum as a special case. Rubinowicz and Bohr have explained by the "correspondence principle" and the "principle of selection," respectively, the absence of certain components of spectral lines, predicted by the above theories, so that satisfactory agreement between theory and experiment has been achieved in all respects.

The Petrologists' Club met on Tuesday, January 16. Mr. E. S. LARSEN spoke on *The probable hydrothermal origin of some corundum deposits.* He divided the deposits into two classes, one in which solutions emanating from magmas introduced corundum together with other minerals into surrounding rocks; and another including those formed as veins in peridotites by solutions believed to be the last liquid of the peridotite itself.

A Joint Resolution has been passed by the Senate and the House of Representatives reappointing Mr. HENRY WHITE as a Regent of the Smithsonian Institution, appointing Mr. FREDERIC A. DELANO to succeed the late JOHN B. HENDERSON, and Mr. IRWIN B. LAUGHLIN to fill the vacancy caused by the expiration of the term of the late ALEXANDER GRAHAM BELL.

The National Gallery has now on exhibit in the Evans Room a collection of antique Etruscan, Greco-Roman and Byzantine jewelry, ancient glassware and pottery, dating from the Seventh Century, B.C. to the Eleventh Century, A.D., lent by the Archaeological Society of Washington.

A considerable collection of antiquities from a pit house in Chaco Canyon, New Mexico, was presented to the U. S. National Museum in January by the National Geographic Society and is now being cataloged in the Division of American Archeology. Objects from the subterranean dwellings are extremely rare, for the pit houses antedate most of the prehistoric Pueblo

ruins of the southwestern United States and traces of them have usually been entirely effaced.

Mr. GEORGE W. HOOVER, chief of the Chicago Station of the Bureau of Chemistry, has been appointed chief of the newly created Drug Control Laboratory. Mr. M. W. GLOVER, who has been in charge of the Office of Drug Administration, has been recalled to the U. S. Public Health Service, and Dr. L. F. KEBLER, chemist in charge of the Division of Drugs, has been promoted to the position of chemist in charge of special collaborating investigations and will direct the work involved in the enforcement of the Postal Fraud Law.

Dr. A. HRDLICKA lectures every Friday afternoon, from 5 to 6 o'clock, at the Postgraduate school of the American University, 1901 F Street, on Human Variation, i.e. variation in man's characteristics, both physical and functional. Those who may be interested are invited to attend.

ANNOUNCEMENT

Professor Sommerfield will give the following course of lectures at the Bureau of Standards at 4 p.m. as follows:

	Subject	*Date*
1.	Introduction to Quantum Theory and Its Place in Modern Physics	March 2
2.	Quantum Theory of Spectroscopy, Balmer Spectrum of H, etc	3
3.	Atomic Structure of the Chemical Elements	5
4.	Wave Theory and Quantum Theory	6
5.	The Significance of Quantum Numbers, azimuthal, radial, equatorial, inner, etc	7
6.	Zeeman Effect, Theory of Magneton	8
7.	Line Structure in Complicated Spectra	9

All persons interested are invited to attend. The Bureau of Standards is located at Connecticut Avenue and Van Ness Street, Washington, D. C.